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ANALYSIS OF AIR-TO-AIR COMBAT DATA AND THE EFFECT OF PILOT LEAR--ETC(U)
AUG 78 J E BILIKAN; R K FRICK
ASD/XR-78-3

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Directorate Of Operations Research

ANALYSIS OF AIR-TO-AIR COMBAT DATA
AND THE EFFECT OF PILOT LEARNING

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Analysis of Air-to-Air Combat Data
and the Effect of Pilot Learning,

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August 1978

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Military Capability Improvement Division
Directorate of Operations Research
Deputy for Development Planning
Aeronautical Systems Division
Wright-Patterson Air Force Base, Ohio

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FOREWORD

Co. 4
This is a ~~brief~~ report of a literature search to establish whether or ~~not~~ ^{combat} data obtained from World War II, the Korean War, and the Vietnam War show promise of establishing the existence of a learning effect in pilots who are continually engaged in air-to-air combat over a period of time. Mr. Ralph C. Lenz of ASB requested the investigation.

➤ The study reported is a preliminary effort, and the evidence thus far is inconclusive regarding the existence of a learning effect. Thus, a more detailed follow-on analysis seems justified. It will necessitate further literature search and statistical analysis of more data.

PUBLICATION REVIEW

This report has been reviewed and is approved.

Duane S. Dunlap
DUANE S. DUNLAP, Director
Directorate of Operations Research
Deputy for Development Planning

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I. Introduction

→ A definitive study to establish if a learning effect exists among pilots who routinely engage in air-to-air combat must be based on statistical analyses of combat data. Fundamental to any statistical analysis is an adequate sample size of data, with the data in a form which is appropriate for the hypothesis being tested. —

A literature search for data is therefore the fundamental step in the study we are addressing. Thus far, the literature search has resulted in data which is generally inadequate, for one reason or another. The main source of valid data and results which we presently have is a paper by H. Weiss (Reference 6). The bibliography at the end of Weiss' paper is a potential source of literature, but some of these references have been impossible to obtain up to the present time.

II. Discussion and Results

Some early (World War II) attempts were made to quantify aerial warfare (7), but these references contained little on pilot performance and were concerned mostly with flight dynamics.

R. F. Putrell and the staff of USAF Historical Division, Air University, have compiled volumes on USAF actions in Korea (1), (2). These volumes outline the number of air battles in the Korean conflict and detail some data on combat aces. In particular it was shown that 68% of the pilots who destroyed MIGs were over 28 years old, and that this was significantly greater than the age of the

overall population of combat pilots. It was also shown, by Mr. Futrell, that success and failure in air-to-air combat occurred in grouped events, with many inactive sorties between.

The Korean Air War Summary (3) shows a total of 14,916 air-to-air encounters with almost a 7:1 (900/139) USAF-to-Red kill ratio. Data on individual pilot experience is not available, however, in a span of 13 months, the ratio of aircraft killed (Red/USAF) showed a marked increase from 6/1 to 16/1 in spite of a small initial decrease. (See Table 1) Applying a statistical trend test (4) to the data, a significant trend toward increasing USAF superiority existed. This test however, does not analyze individual duels for pilot survival, since data are not available on previous pilot conflicts.

SEA data is contained in the Red Baron statistics. These statistics have not been fully analyzed by the Red Baron group at Nellis AFB nor the WSEG/IDA group in Washington, DC. Results of individual air-to-air decisive encounters are known but the history of the pilot's previous encounters has not been published (5). To determine pilot survival after a number of encounters will require reviewing the raw data at WSEG/IDA and at Nellis AFB. A sample of a raw data sheet is presented as Appendix B. The number of encounters experienced in SEA is small compared to the Korean data; the clear trend of increasing superiority established in the Korean War has not yet had a chance to be established in SEA.

H. Weiss (6) has written a paper which includes some statistics on pilot survival in air-to-air combat. Weiss finds from NW I

TABLE 1

USAF Claims/Kills and Losses In
Korean War Air-to-Air Combat*

<u>Time Period</u>	<u>Enemy Aircraft Destroyed</u>	<u>USAF Aircraft Destroyed</u>	<u>Rounded Ratio Enemy Dest/ USAF Dest</u>
July-Sept 1950	32	5	6/1
Oct-Dec 1950	17	4	4/1
Jan-March 1951	17	4	4/1
Apr-June 1951	40	11	4/1
July-Sept 1951	30	10	3/1
Oct-Dec 1951	88	31	3/1
Jan-March 1952	87	13	7/1
Apr-June 1952	97	18	5/1
July-Sept 1952	116	15	8/1
Oct-Dec 1952	83	13	6/1
Jan-March 1952	98	8	12/1
Apr-June 1952	163	5	33/1
July 1953	32	2	16/1
Total	900	139	7/1

* Adapted from "Korean Air War Summary: Organizations Under the
Operational Control of FEAF, 25 June 1950 - 27 July 1953"

Archives File No: K720.04D-1.

American and French, WW I German, and WW II German data the probability of a pilot being killed on the j -th decisive encounter. A decisive encounter is defined as an air-to-air encounter where one of the opponents is downed. The probability curve (Figure 1) shows a curvilinear decrease in the probability of being killed as the number of encounters increases, as would be expected when a learning effect exists. The curve levels off at a probability of 0.02 after about ten encounters.

Next, H. Weiss proceeds to hypothesize "survival of the fittest" as the reason for the decline in attrition. To support this view he calculates the distribution of "probability of survival" from each encounter, assuming the probability of survival will be drawn from a stationary distribution at each encounter. From the data, the distribution from which the chance of survival is drawn at each encounter was calculated and has a U shape (Figure 2), or a bimodal form. This indicates that pilots are either skilled or relatively unskilled, few pilots being of moderate skill. The calculation of the U-shaped distribution is a result of the hypothesis that "the survival of the fittest" is the phenomenon which is present. In other words, the U-shaped curve is a result of an hypothesis, it is not additional evidence of the premise of "survival of the fittest."

One could argue that the Korean War data, which shows a trend towards increasing USAF superiority, would support the hypothesis that a learning effect is present. However, one could

also have such a trend if "survival of the fittest" were the predominate effect. Such an effect would cause an enrichment of the population of good pilots as time elapsed which would mean that combat scores of the pilot population as a whole would get better.

To fully test the hypothesis of a learning effect in air-to-air combat will probably involve a two-fold approach. One would be analyses of combat data on individual pilots and the other would be to test for a learning effect under controlled experimental conditions. This latter approach is necessary in order to have subjects remain "alive" to determine if they gained experience from the previous encounter.

One's intuition suggests that probably both effects, survival-of-the-fittest due to innate skills and learning by exposure to repeated combats, are present. There is also a third effect which comes to mind, and that is, the interaction with enemy skill level, and whether that skill level changes with time. This additional consideration is an argument against relying exclusively on combat data to test the hypothesis of learning, because there are so many uncontrolled factors present; one does not really know what is causing the variations in fraction of pilots surviving. Controlled laboratory conditions, i.e., simulation, may be the only answer.

This has been a preliminary report. We propose to follow this with a more detailed and rigorous presentation on the shortcomings of analyses of combat data, even if such data were available, and a proposed experimental approach to testing the learning hypothesis.

FIGURE 1
PILOT LOSS RATE AS A FUNCTION
OF ENCOUNTER NUMBER

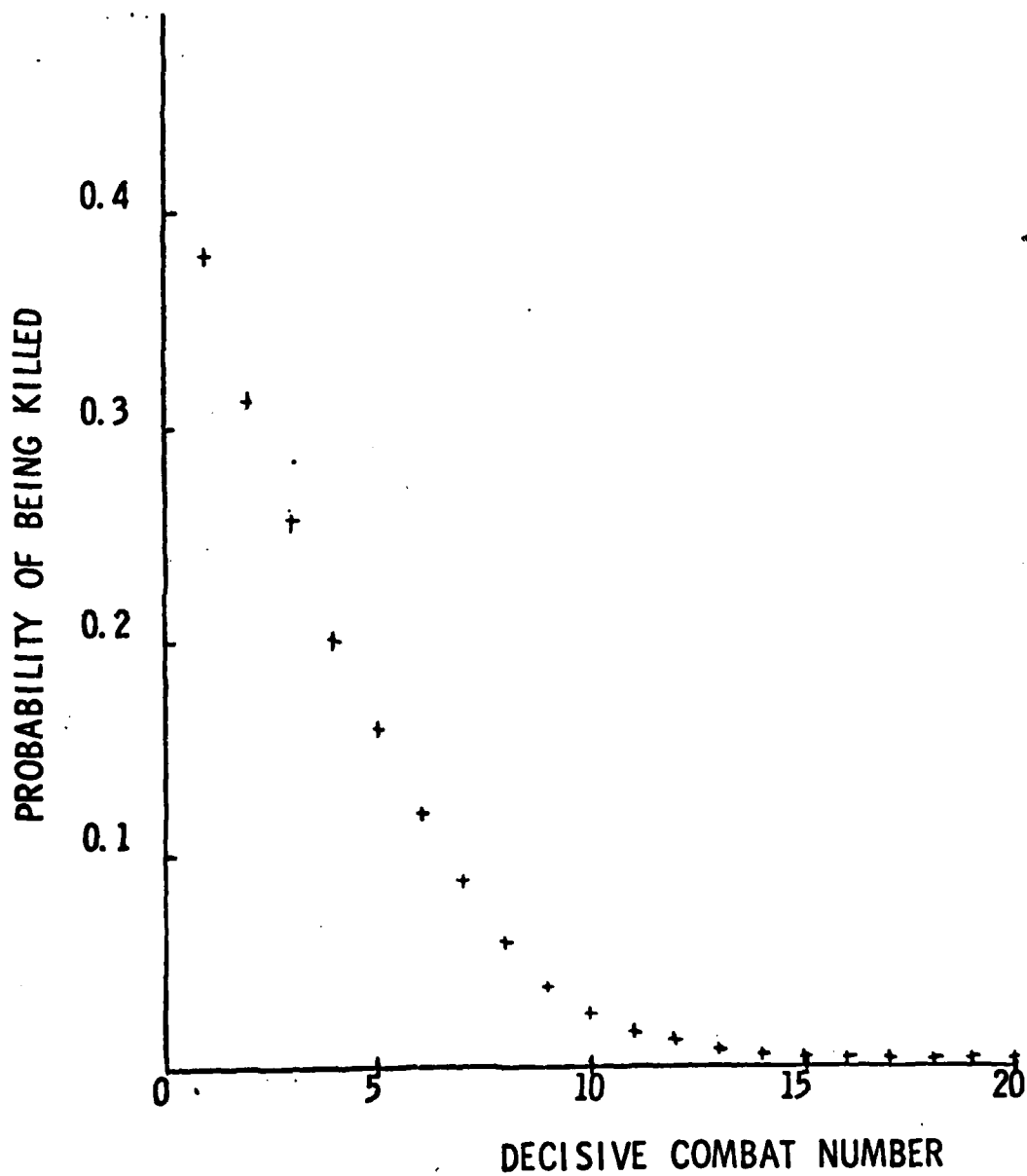
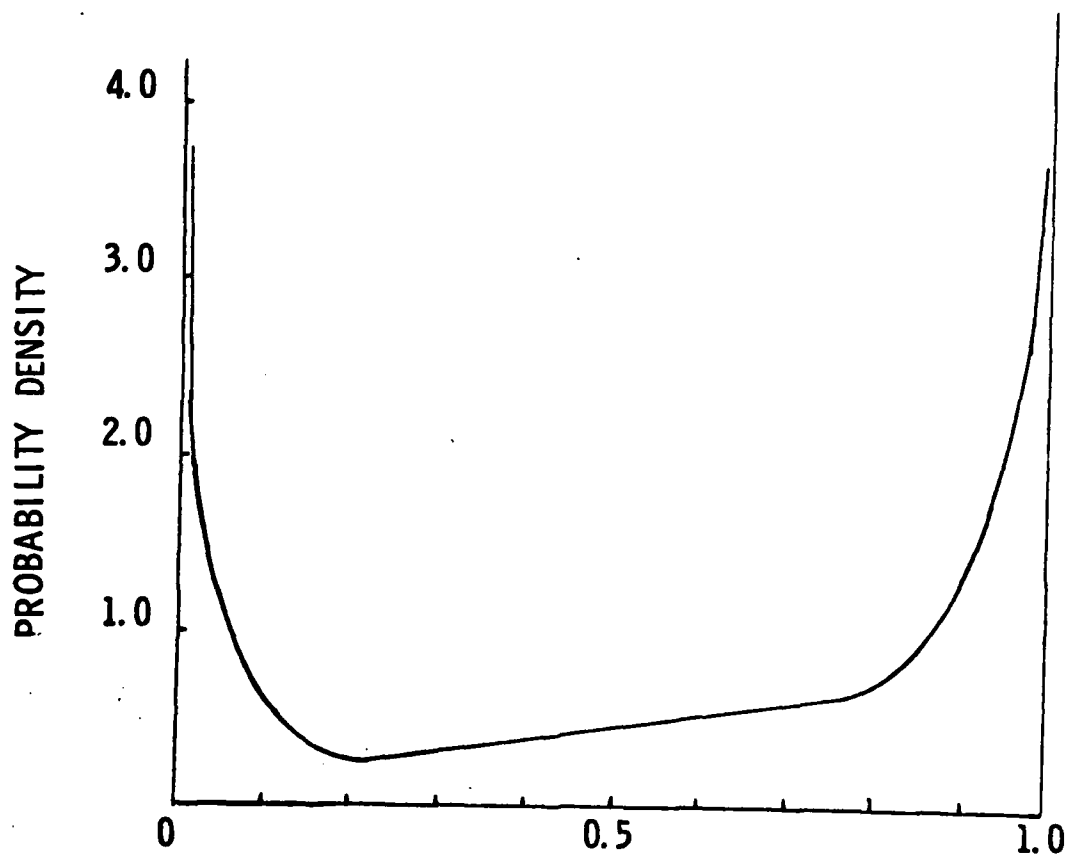


FIGURE 2
PROBABILITY DENSITY FUNCTION
OF PILOT PERFORMANCE



APPENDIX A

Extracts from the Paper
by H. Weiss

Air-to-Air Combat

Aircraft are lost to enemy aircraft as well as to flak. Data on past air combat was therefore examined to determine a basis for a model of this phase of air operations. In attempting to develop an analytical model to represent the Battle of Britain, the author found that there was a strong indication that each side lost aircraft in proportion to the number committed to the air battle, relatively independently of the number of enemy aircraft present. At the same time it was noted that in all past wars involving extensive air-to-air combat, a small number of pilots—the aces—were responsible for most of the kills. It was therefore hypothesized that fighter force capability depended on the performance of a few top pilots rather than numbers of pilots and attention was shifted to measures of pilot performance. The following routine was employed to obtain a measure of pilot effectiveness:

A "decisive combat" is defined as one in which a pilot is either killed or adds one to his score. (It is recognized that the method is dependent on consistency of the scoring system and the results depend on the mix of enemy aircraft types.)

Then the flow diagram of Figure 13 traces the progress of a pilot from his first combat through his last.

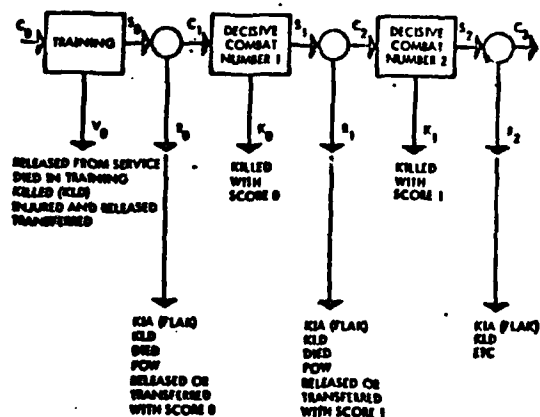


Figure 13. Fighter Pilot Activity Flow

Let

T_j = total number of pilots, living and dead with score "j"

K_j = number of pilots KIA by enemy aircraft with score "j"

R_j = number of pilots leaving combat, other than KIA in air combat, with score "j"

C_j = number of pilots entering their jth decisive combat

p_j = probability that a pilot will be killed in his jth decisive combat

$S_j = \sum_{s \leq j} T_s$ = total number of pilots living or dead with at least score j (24)

and

$$p_j = K_{j-1} / (S_j + K_{j-1}) \quad (25)$$

Although a moderate amount of information is available on Aces, 18, 19 data was located on only three organizations which permitted computation of p_j for pilots with scores of 1 to 4. These were Richthofen's Jagdgeschwader Nr. 1,²⁰ and American pilots serving with the French (including the Lafayette Escadrille)^{21, 22} in World War I, and Jagdgeschwader JG 26 in World War II²³ for these three organizations, p_j is plotted against score in Figure 14.

The initial almost vertical drop in probability of being killed between decisive combats one and five was completely unexpected.

The value of about 0.02 in the range 10-30 is consistent with similarly computed values for American Aces in World War II and Korea, which fell in the range 0.01 to 0.03.

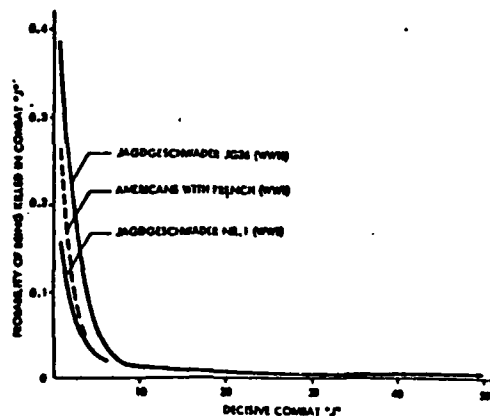


Figure 14. Fighter Pilot Loss Rate versus Score

The question immediately arises whether the initial decline in p with score represents learning, or the elimination of the least skilled pilots. An improvement factor of twenty in five "trials by combat" seems less likely to the writer than the hypothesis that Figure 14 represents the survival of the fittest.

Since a pilot's "score" includes reconnaissance aircraft and bombers as well as fighters, the records were examined to see whether the high scores were based largely on "sitting ducks." This was found not to be the case; a fair estimate appears to be that on the average a pilot's score contains both fighters and other aircraft in fairly equivalent numbers. If non-fighter aircraft are easier targets, therefore, the descent of the " p " curve in a pure fighter environment would be even steeper, by a factor of perhaps 2.0.

The following analysis was therefore performed. It was assumed that the capability of a pilot entering combat could be represented by a value " s ," the probability that he would survive a decisive combat, and that " s " characterized his skill and changed insignificantly in successive combats. (A modified model might of course allow for some learning.) The fraction of pilots of capability " s " is described by the probability density function $f(s)$. Between decisive combats it was assumed that all pilots regardless of skill, had an equal probability of leaving combat. Define

$$v_j = \int_0^1 s^j f(s) ds \quad (26)$$

i. e. this is the expected fraction of the initial force surviving " j " decisive combats. Subject to the additional assumption of equal probabilities of withdrawal between combats,

$$p_j = 1 - (v_j/v_{j-1}) \quad (27)$$

hence

$$v_j = \prod_{k=1}^j (1-p_k) \quad (28)$$

and v_j can be computed from the data. Since the v_j are the moments of the distribution $f(s)$, $f(s)$ may be computed from them and this has been done.

Figure 15 shows $f(s)$ plotted against probability of being killed, $(1-s)$. The U-shaped distribution is surprising—there seem to be few "average" fighter pilots. Again, an initial conjecture that the distribution might be normal, turned out to be unsupportable. Figure 16 which cumulates the probability density function shows that for this data, at best fewer than 15 percent of the pilots had a better than even chance of surviving their first combat.

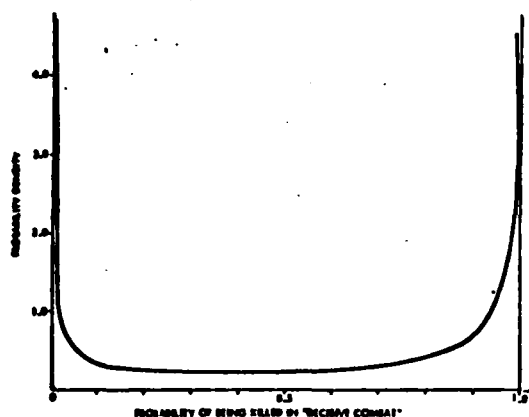


Figure 15. Probability Density Function of Pilot Performance

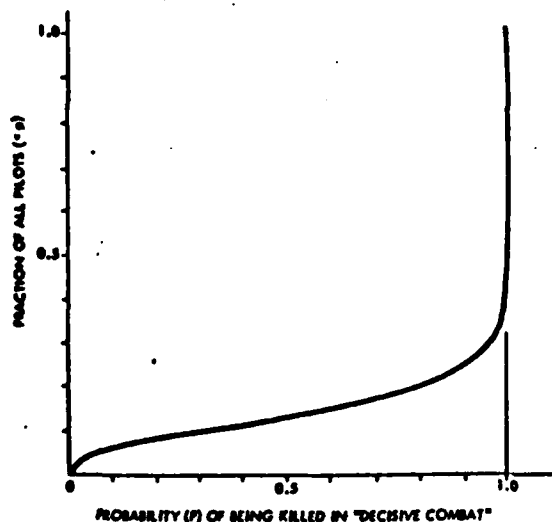


Figure 16. Cumulative Distribution Function of Pilot Performance

Next examining the scores of the top ten fighter pilots of several countries in both world wars. Figure 17 shows the tremendous contribution of a small number of men. The high reported score of the German Pilots²⁴ (which will undoubtedly be the subject of argument ad infinitum) becomes plausible when one compares their values of "p" and their loss rate, in Figure 18. With "p" of 0.01 to 0.02 (typical of all Aces of all countries) and no rotation, the expected number of kills per Ace before he is shot down is 50 to 100, and individuals with scores of several hundred are not unexpected.

	WW I	WW II
UNITED STATES	143	294
ENGLAND	562	314
GERMANY	497	7568

Figure 17. Total Scores of Top Ten Aces

SERVICE		RANGE OF SCORES	p	PERCENT ACES IN RANGE KIA
UNITED STATES	8TH AF/EUROPE	10-28	0.015	7
UNITED KINGDOM	RAF	20-38	0.024	10
GERMANY	JG-26	10-30	0.018	44
		31-197	0.009	35

Figure 18. Comparison of Single Combat Loss Rate and Cumulative

A schematic model of air-to-air combat now suggests itself. At the same time, it is interesting to consider the effects of a policy which uses combat outcome as a basis for upgrading average pilot skill. For this paper it is assumed that both forces operate from sanctuary bases, that only fighters are involved, and that one side attempts to rescue its pilots who survive the loss of their aircraft. The model is diagrammed in Figure 19.

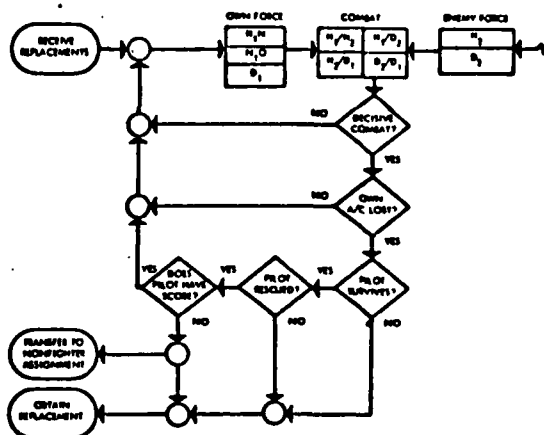


Figure 19. Air-Air Combat Activity Flow

It is further assumed that there are only two classes of pilots, "Hawks" and "Doves," that Hawks represent 10 percent of replacement pilots and cannot be identified before combat. Combat takes place between two aircraft at a time; the probability that each combat involves Hawks, Doves, or one of each, is proportional to their representation in the individual forces. Hawks always shoot down Doves, and a Hawk has an even chance against an enemy Hawk. Combat between Doves results in no loss. Forces on both sides are equal, and aircraft and pilots are replaced as they are lost. Pilots may survive the loss of their aircraft with specified probabilities. (Some German Aces of World War II are reported to have been shot down six times or more and survived.)

Rescuing pilots recovers the investment in training, but does not improve force effectiveness drastically, unless coupled with a selection process. It is therefore further assumed that each rescued pilot with a score of one or more returns to combat; but that rescued pilots shot down without score are transferred to noncombat flying duties.

The result of this selection process is a substantial increase in the effectiveness of the force employing it, with Figure 20 showing the results. If 80 percent of pilots survive the loss of their aircraft and all are rescued, with those having prior scores returning to the combat, the force effectiveness is tripled in a sustained combat.

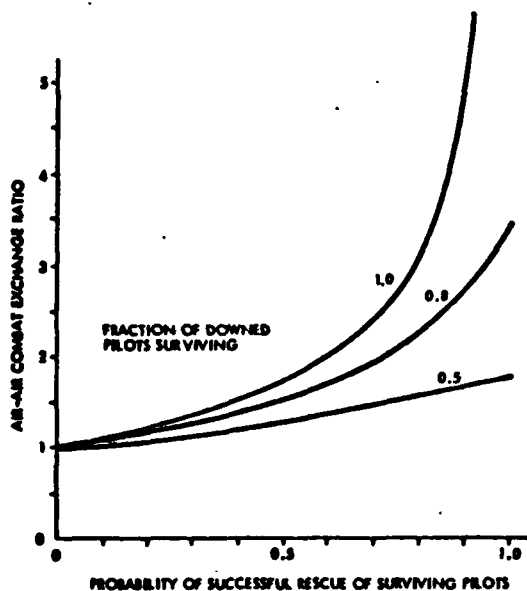


Figure 20. Effect of Rescue Plus Selection Doctrine on Force Effectiveness

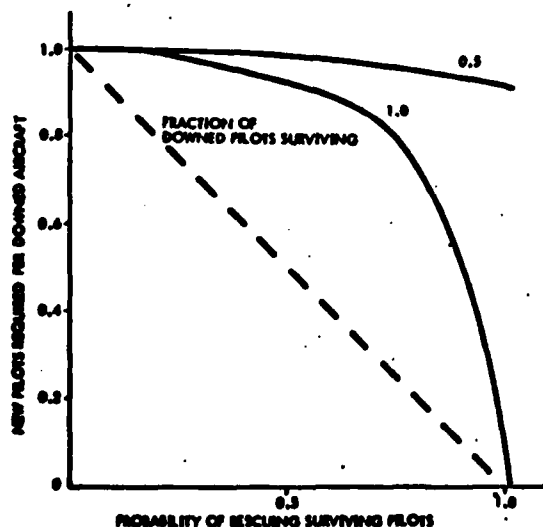


Figure 21. Effect of Rescue Plus Selection Doctrine on Pilot Replacement Rate

Figure 21 shows the required pilot replacement rate. Figure 21 may be misleading, the new pilots required per downed enemy aircraft depends only on the rescue rate, to a first approximation.

On the other hand, if the precombat training and screening process delivers only "Hawks" to one side, that side may have a 10:1 sustained exchange ratio, at all times.

Discussion of Air-to-Air Combat

The foregoing analysis and model has said nothing about equipment characteristics. It is clear that both equipment and men are vital. Prolonged major wars in the past have tended to witness the development of aircraft of compatible performance on both sides. In all wars these differences have been far overshadowed by the performance of Aces, as individuals.

Before Korea it was believed that air-to-air combat between fighter aircraft was obsolescent, or would be combat between machines, gun sights, and computers. Events turned out otherwise. The writer suggests that the increasing complexity of equipment, and the incredibly demanding environment of air combat will only reduce to even smaller numbers, those individuals who can master their equipment and the combat environment, and whose presence as dozens, within a force of hundreds, or thousands, will be decisive.

It seems clear, in addition, that any realistic assessment of the capabilities of projected equipment must properly account for the variability of individual performance, and allow the selection and maximum exploitation of the rare capabilities of the best operators, while raising to a maximum the performance of the less skilled. Conversely an attempt to assess the performance of equipment must correct for the variability of the humans who operate it.

Conclusion

This paper has proceeded from a broad discussion of the objectives of system analysis through the outlining of the structure of a large and complex operation to the development of specific submodels and their interrelationships to combat data, and to system performance parameters.

In *War and Peace* Tolstoy had Prince Andrew remark:

"What theory and science is possible about a matter the conditions and circumstances of which are unknown and cannot be defined, especially when the strength of the acting forces cannot be ascertained? ... What science can there be in a matter in which, as in all practical matters, nothing can be defined and everything depends on innumerable conditions, the significance of which is determined at a particular moment which arrives no one knows when?"

But the experience of the past half century is that more can be known about the "calculus of conflict" than was envisioned by the Prince. The analyst is always subject to the overriding judgment of military experience, but increasingly that experience and judgment are susceptible to expression in quantitative terms.

The methodology now exists for producing analytical tools of convincing verisimilitude—but both the analyst and the military user must continue to remain aware of the fact that this appearance of truth may be false, that the validity of an analysis is subject to proof in the "moment of truth" on the battlefield, that verification is of such importance that all possible avenues of test from field exercises to combat records must be utilized.

-
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APPENDIX B

**Sample Data Sheet
Project Red Baron**

RED BARON
MIG INCIDENT SUMMARY

I. BASIC DATA

Event No. _____
 Date/Time _____
 Service/Unit _____
 No. & Type A/C: _____
 U.S. _____
 Enemy _____

II. MISSION DATA

<u>Mission</u>	<u>Location of Encounter</u>	<u>Kill/Damage</u>		<u>Ordnance</u>	
		<u>U.S.</u>	<u>Enemy</u>	<u>U.S.</u>	<u>Enemy</u>

III. PILOT DATA

<u>Flight Pos. & Call Sign</u>	<u>Name, Rank, S/N</u>	<u>Dwn/ Dmg</u>	<u>Weapons Fired</u>	<u>Enemy K/D</u>	<u>Present Location</u>	<u>Inter- viewed Date/By</u>

IV. IDENTIFYING COMMENTS

V. NOTES

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